



## Development of Low-Temperature Solid Oxide Fuel Cells

Among the fuel cell systems currently being developed, the solid oxide fuel cell (SOFC) offers significant advantages for residential and auxiliary power units, as well as for larger industrial power applications.

The goal for all fuel cells presently is to reduce both stack and system costs to make them competitive with existing technologies. While the current SOFC operates at 1000°C, this high temperature has limited the materials that can be used for the various cell components (electrolyte, anode, cathode, and interconnect or bipolar plate) to relatively expensive ceramic compositions. In addition, there are concerns with the materials and manufacturing costs of other components within the hot zone of the fuel cell, which are normally ceramic-based (e.g., manifolds, piping, and insulation).

Much of the present R&D activity is focused on developing SOFC materials for use at 800°C, which is low enough that alternative materials become available to reduce cost significantly. Further reduction in operating temperature, to 500-700°C, could yield even greater cost savings.

In addition to materials flexibility and cost, the lower SOFC operating temperatures result in higher Nernst and cell voltages, leading to increased energy conversion efficiencies. Further, the lower operating temperatures would permit close and efficient thermal integration with a fuel reformer for converting hydrocarbon fuels to a hydrogen-rich gas. For example, a typical catalytic-autothermal reformer operates between 750 and 850°C. Thus, a fuel cell operating at about 800°C would be ideally suited for optimal thermal integration between these two key components. The reduced operating temperature

would also improve mechanical robustness and reduce thermal stresses and chemical interactions among the various cell components. However, operating the SOFC at lower temperatures significantly increases the performance requirements for the cell components.

The decrease in the performance of the cathode as the temperature is reduced is the most significant issue facing development of lower temperature SOFCs. The lack of ionic conductivity in the conventional manganite-based perovskites limits their use as the cathode at the lower temperatures. Mixed electronic-ionic conductivity is essential in the cathode material to permit the oxygen reduction to occur over the entire electrode surface rather than being restricted to the three-phase region of electrode, electrolyte, and gas phase.

Current research at CMT is focused on developing alternative cathode materials for use with thin-film electrolytes of gadolinia-doped ceria or yttria-stabilized zirconia, which operate over a temperature range of 500-850°C. Half-cell tests at these temperatures showed promising results for a number of perovskite-based cathodes, as well as some layered structures. The figure on the next page shows the area specific resistances measured for candidate cathode materials with the two electrolytes at various temperatures. The best-performing cathode on yttria-stabilized zirconia was a strontium-doped lanthanum ferrite, which has low resistance, stable performance, and low overpotentials under galvanostatic conditions. The best-performing cathode on gadolinia-doped ceria was a strontium-doped gadolinium cobaltite, again displaying low resistances with a fairly stable long-term performance. With these alternative cathode materials, the target area

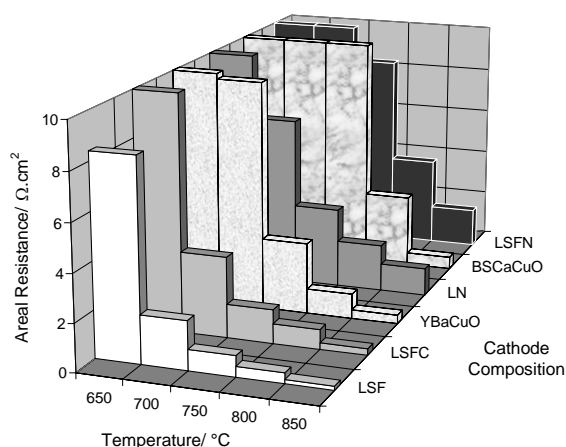
specific resistance of  $<1 \Omega \cdot \text{cm}^2$  was achieved for yttria-stabilized zirconia at  $800^\circ\text{C}$  and gadolinia-doped ceria at  $650^\circ\text{C}$ . Further reductions in temperature and area specific resistance for cathodes with both electrolytes are desirable.

Although we have placed a strong emphasis on cathode research, other relevant materials issues for the SOFC are also being investigated in CMT. Anodes that are tolerant to sulfur in the fuel have gained interest recently because they could potentially remove the fuel reformer from within the system, resulting in reduced costs. Various materials

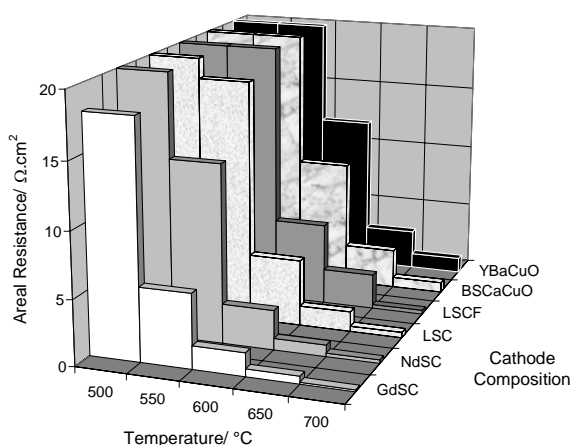
strategies are being explored to attack this problem. The search for an improved metallic interconnect also continues, a necessary component within the stack at lower temperatures.

## ANL Participants

James M. Ralph, Xiaoping Wang, Terry A. Cruse, Jules L. Routbort, Romesh Kumar, and Michael Krumpelt. For further information contact Michael Krumpelt at (630) 252-8520 or [krumpelt@cmt.anl.gov](mailto:krumpelt@cmt.anl.gov).



LSF = lanthanum strontium ferrite  
 LSFC = lanthanum strontium cobalt ferrite  
 YBaCuO = yttrium barium copper oxide  
 LN = lanthanum nickelate  
 BSCaCuO = barium strontium calcium copper oxide  
 LSFN = lanthanum strontium nickel ferrite



GdSC = gadolinium strontium cobaltite  
 NdSC = neodymium strontium cobaltite  
 LSC = lanthanum strontium cobaltite  
 LSCF = lanthanum strontium iron cobaltite  
 BSCaCuO = barium strontium calcium copper oxide  
 YBaCuO = yttrium barium copper oxide

*Area Specific Resistance for Various Cathode Compositions on Yttria-Stabilized Zirconia Electrolytes (left) and Gadolinia-Doped Ceria Electrolytes (right)*